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Formation and study of the RRAM memory elements by local anodic oxidation method

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One of the current trends in the electronic development is the development and research of resistive memory (RRAM) elements based on memristor structures, which is faster than modern memory, but it is non-volatile, which allows to reduce the power consumption of portable devices and increase the operating time without additional charging.

The analysis of publications has shown that most methods for forming memristor structures for resistive memory contain a complex stage of electroforming oxide nanosized structures (ONS) to give them memristor properties. However, the application of the local anodic oxidation (LAO) method using atomic force microscopy (AFM) techniques makes it possible to form the titanium ONS exhibiting a memristor effect without additional electroforming of structures, which will simplify the technology of manufacturing RRAM memory modules [1-2]. Therefore, the goal of the work is the development of manufacturing technology and the formation of memory elements RRAM based on memristor structures by the method of local anodic oxidation.

In the course of the work, a structure of memory elements RRAM was proposed, which is a cross-bar array of memristor structures containing an insulating SiO_2 substrate, structures of the lower titanium electrodes, and titanium ONS obtained by the LAO method and the structure of the upper electrodes (Fig. 1).

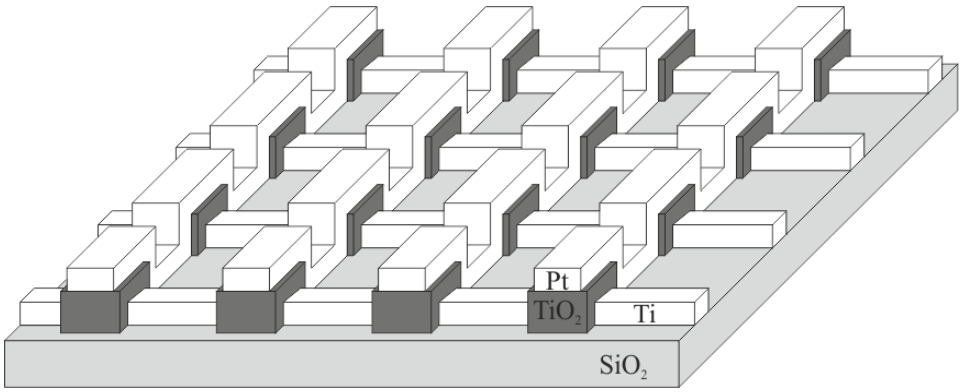
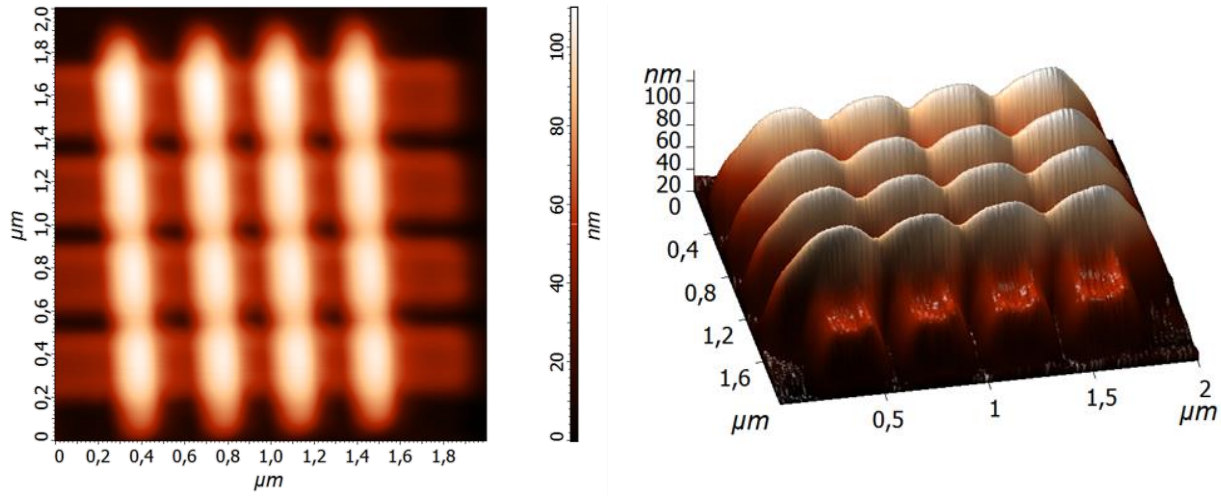


Figure 1. The layout of the memory elements of RRAM based on memristor structures.



(a) (b)

Figure 2. (a) Topography and (b) 3D-image of the RRAM memory element layout.

On the basis of the proposed structure, a technological route for manufacturing the cross-bar array of the ONS titanium was developed. To do this, a SiO_2substrate is used, by which a thin film of titanium with a thickness of 20 nm was deposited by magnetron sputtering. Then, by the method of focused ion beams, lithography was carried out on the titanium film, resulting in the structures of the lower electrodes. After this, the LAO of the lower electrodes was used to form the memristor ONS of titanium. At the final stage, ion-stimulated deposition of the structures of the upper electrodes based on platinum was carried out. As a result, a model of the memory element RRAM was constructed on the basis of 16 memristor ONS (Fig. 2).

Investigation of the electric characteristics of the array showed that the obtained titanium ONS exhibit a memristor effect and switch between the high and the low resistance state (Fig. 3).

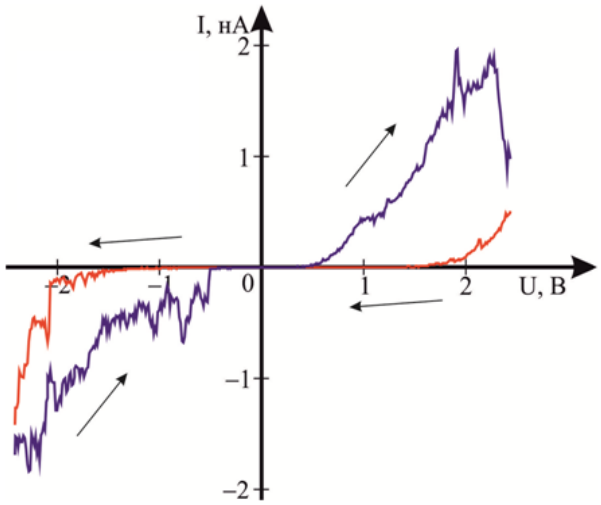


Figure 3. Volt-ampere characteristic of the titanium ONS obtained by the LAO method.

Thus, it was shown that the method of local anodic oxidation can be used in the formation of resistive memory elements. The obtained results can be used in the development of technological processes for manufacturing the elemental base RRAM on the basis of oxide nanosized titanium structures using probe nanotechnology.

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1. V.I. Avilov, O.A. Ageev, A.S. Kolomiitsev, et al., *Semiconductors* **48**, 1757 (2014).
2. V.I. Avilov, N.V. Polupanov, V.A. Smirnov, et al., *Materials Science and Engineering* **256**, 5 (2017).